

"Limits of Nb₃Sn" Working Group Preliminary report

43rd INFN Eloisatron Workshop Super Magnets for Supercolliders Erice, October 26 – November 1, 2003

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Proposed work plan

 Concentrate on very high field magnets (LHC upgrade is the most likely application in the "near" term) **Discussion Topics:**

- Coil Design
- Mechanical support & assembly
- conductor, operating temperature
- aperture, field quality, dyn. range \Leftrightarrow accelerator physics w.g.
- stored energy, inductance
- radiation issues
- magnet cost

- ⇔ conductor/materials w.g.
- ⇔ quench protection w.g.
- ⇔ ancillary systems w.g.
- \Leftrightarrow all of the above
- Establish R&D targets? (as for DOE conductor program)



Coil Design

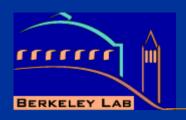
- Concentrate on cosθ and block for very high field
- Main differences are cable and stress distribution
- Cable: need more work on keystoned cables
 - assess mechanical and degradation limits
 - special cores to increase keystone limits
- Stress distribution vs. field
 - after discussion, agreement on basics stress characteristics
 - perform more detailed comparisons (stress maps)
- Also consider efficiency and cost factors
 - complexity (design, parts and assembly)
 - flexibility, in particular for R&D
- Keep exploring new ideas (comb. function, warm iron etc.)

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Mechanical Support

- Several mechanical support concepts are being explored:
 - collars; Al clamps
 - bladders (no keys); bladders (with keys)
 - rods/bolts, wire wraps
- There are issues that need to be addressed for each concept
 - Bladders: long magnets, position & alignment accuracy
 - Collars: springback, total stress delivered
 - •
- Very robust performance has been demonstrated for Nb₃Sn
- Some of the developments can be beneficial to NbTi as well



Stress limits

- RD3b, HD-1 show limits are higher than previously thought
- However, no clear boundaries have been established
- Dedicated experiments are necessary
- Sub-scale tests are attractive but feasibility is not obvious
- Small coil tests in full scale structure are one possibility
- Insert coil tests in full scale magnets are another possibility
- Correlation needed between strand and magnet performance
- Stress criteria for strands may then be established



Quench performance & training

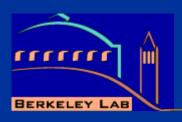
- Magnet quench performance & training needs to be improved
- Fundamental performance and cost issue, esp. at high field
- Different viewpoints on mechanisms causing premature quenches
- Different viewpoints on best R&D strategy & tools
- Systematic analysis of quench mechanisms is needed
 - Theory: 3D modeling available
 - Experiments: special instrumentation can be developed
- Examples of effects to be investigated:
 - Effect of face side shear, high preload & bond vs low preload and let slip
 - Quench mechanism in ends, methods of preload
 - Issues with ramps, transitions and joints

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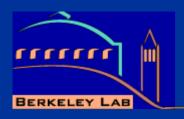
Conductor (1)

- A lower copper fraction may be feasible for RRP wires
 - Ic increase by +20% gives +0.5 T in HD-1 at 4.2 K
 - Well worth pursuing! some risk (drawing, cabling)
- Focus on 15T+ J_c improvements (change J_c criterion to 15T)
- Low magnetization is not a priority for near term magnet development
- However, better stability is a priority (both flux jump and MQE)
- A D_{eff} goal of \leq 50 μm appears to be satisfactory for the near term
 - keep pushing on Ic, high field Jc and stress tolerance instead
 - A statement from AP is required regarding LHC luminosity upgrade specs
- Much smaller filaments may be ultimately needed develop in parallel?



Conductor (2)

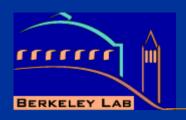
- Ic measurements at 1.9 K in 16-20 T range are needed
- Further R&D on keystoned cables required for cosθ designs
 - Some work already planned in connection with LARP
- Pay close attention to new conductors (e.g. with SM "technology" tests)



Proposed Magnet R&D Targets

• Technology:

- #1: Bore field ≥ 18 T with ≥ 5 mm clear bore
- #2: Bore field ≥ 16 T with ≥ 30 mm clear bore (cold bore included)
- #3: Bore field ≥ 14 T with ≥ 3 m magnetic length
- Dipoles ($B_0^{\text{nom}}=14 \text{ T}$, harmonics as measured at 10 mm physical radius):
 - #4: All central harmonics ≤ 3 units at B_0^{nom}
 - #5: All central harmonics ≤ 10 units from $0.1*B_0^{nom}$ to B_0^{nom} @ LHC R.R.
- Quadrupoles (Gnom=200 T/m, harm. as measured at 20 mm physical radius)
 - #6: All central harmonics ≤ 3 units at G^{nom}



Summary

- 16 Tesla achieved, and there is still a lot of potential
- More R&D needed to select best coil configuration for each application
- Several concepts for mechanical support are being developed
- Robust mechanical behaviour demonstrated for Nb₃Sn magnets
- Systematic experimental analysis of stress limits is needed
- Systematic theoretical/experimental analysis of quench/training is needed
- More high field Jeff is still the highest priority for conductor development
- Proposing magnet R&D targets to help focus and measure progress